Ultrafine Grained Steels Fabricated by Novel Processes -Microstructure Evolution & Mechanical Properties-

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ABSTRACT

Ultrafine grained (UFG) steels whose mean grain sizes are smaller than 1 μm have been energetically studied in this 5 years. It is expected that ultra-grain refinement would enable us to have the advanced steels with superior properties in simple chemical compositions. Severe plastic deformation (SPD) and ultimate thermomechanical processing have realized the UFG steels at least in laboratory levels. The author originally developed a novel SPD process, named accumulative roll-bonding (ARB), with his colleagues in 1999 [1], and has succeeded in fabricating UFG sheets of various kinds of metals and alloys by ARB. The principle of the ARB process is shown in **Fig.1**. **Figure 2** indicates typical UFGs in the IF steel ARB processed by 7 cycles (ε=5.6) at 500°C. The sheet is filled with the elongated UFGs with mean grain thickness and length of 210 nm and 700 nm, respectively, which are surrounded by high-angle grain boundaries. The detailed microstructural and crystallographic analysis like Fig.2 has clarified that the formation of the UFGs during SPD (ARB) can be understood in terms of *in-situ recrystallization* (or *continuous recrystallization*), which is characterized by ultrafine grain-subdivision and recovery to form more equilibrium grain boundaries [2]. The mechanical properties of the ultrafine grained materials were systematically clarified by using the variously grain-sized materials fabricated by ARB followed by annealing. **Figure 3** is an example of stress-strain curves of the UFG aluminum and IF steel. It is interesting that the two different materials show quite synchronized mechanical behaviors. The UFG materials perform very high strength compared with the starting materials having conventional grain sizes. On the other hand, the UFG sheets of single-phase materials have limited uniform elongation, which is due to early plastic instability caused by the lack in strain-hardening [3].

If time allows, another novel and simple route to obtain nanostructured low-carbon steels [4] will be introduced. In this process, martensite is used as a starting structure. Only 50% cold-rolling produces complicated deformation microstructures equivalent to SPD materials, and subsequent warm annealing produces multiphased UFG structure composed of UFG ferrite, uniformly precipitated nano carbides, and small amount of tempered martensite blocks. The steel with multiphased nano-structure performs both high strength and adequate ductility.

References

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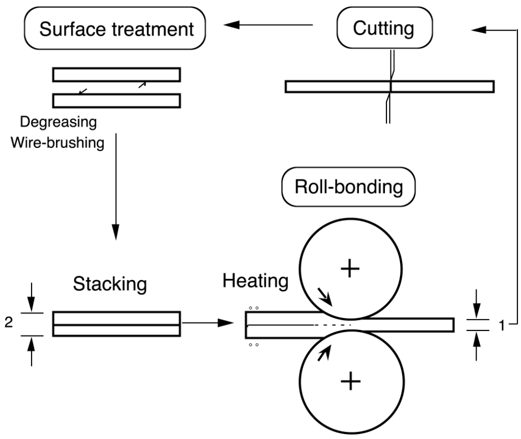

Fig.1 Schematic illustration showing the principle of the ARB process.

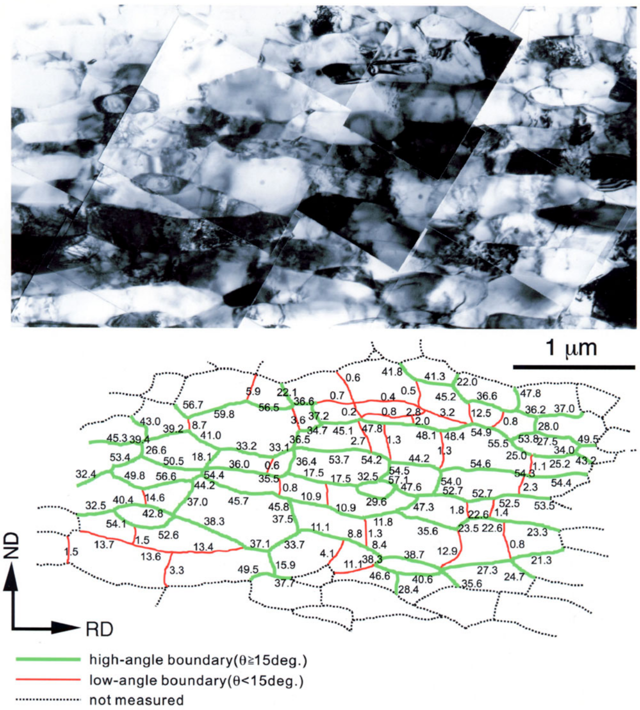

Fig.2 TEM microstructure (a) and corresponding misorientation map (b) in the IF steel ARB processed by 7 cycles (ε=5.6) at 500°C. Observed from TD. The misorientations (deg.) indicated in (b) were measured by means of Kikuchi-line analysis in TEM.

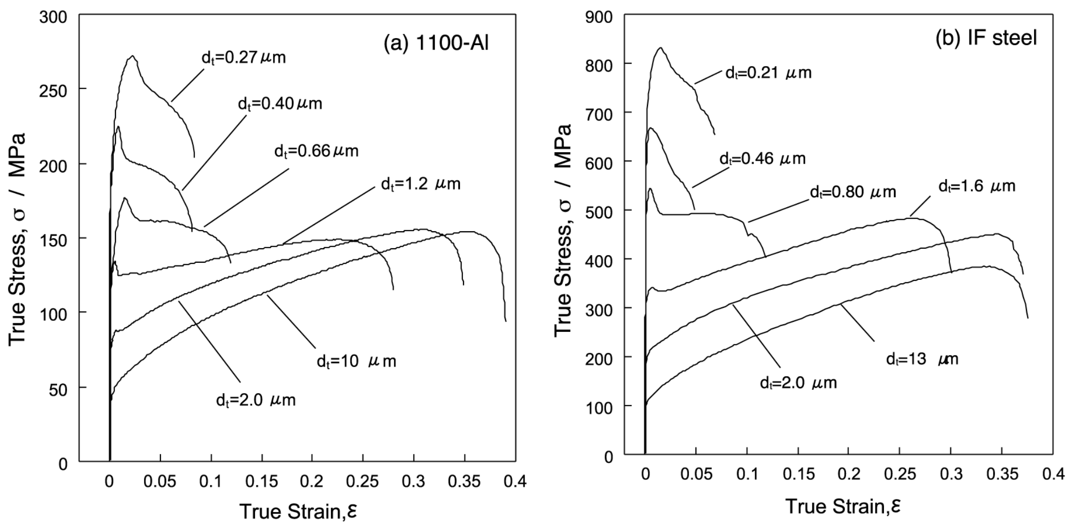

Fig.3 (True stress)-(true plastic strain) curves of the (a) 1100-Al and (b) IF steel with various grain sizes fabricated by ARB and subsequent annealing.